

## Water Consumption

①

What is the major ingredient in brewing? - Water.

How much is used?

$$\frac{6 \text{ volumes water}}{\text{Volume of beer}} \quad \{ \} \quad \text{liters / gallons / barrels / etc}$$

### 6 - Broken down

Brewing Water - 2.7 volumes

Process Water - 2.1 volumes

General purpose - 1.0 volumes

Service Water - 0.2 volumes

Brewing water - water that makes the beer, comes in contact with brewing ingredients.

- mashing / lautering water
- Post boil adjustment water
- Evaporation

Spent grains -

20% grain

80% water

Example

100 lbs 2-row CG 76.5 %

Assuming 100% BtE

= 76.5 lbs extracted

23.5 lbs spent grain

$$\frac{23.5}{0.2} = 117.5 \text{ lbs (grain + water)}$$

↓

$$(\times 0.8) = \boxed{94 \text{ lbs water}}$$

Gravity Adjustments

$$C_1 V_1 = C_2 V_2$$

$$C = GU \text{ or } ^\circ P / ^\circ B$$

$V = \text{volume}$

Gravity Units - GU

$$GU = (SG - 1)(1000) \times (\text{Volume})$$

ex

$$\begin{array}{lcl} 1.060 & SG & \\ 10 & \text{gallons} & \end{array} = GU = 60$$

To adjust a gravity

Have 100 barrels of 1.058 unfermented wort, what volume of water must you add to get an SG of 1.048?

$$\frac{(100 \text{ Barrels})(58 GU)}{(48 GU)} = 120.8 \text{ Barrels Total}$$

$$120.8 - 100 = 20.8 \text{ Barrels added}$$

or

$$\frac{(100 \text{ Barrels})(14.5 ^\circ P)}{12 ^\circ P} = 120.8 \text{ Barrels Total}$$

$$= 20.8 \text{ Barrels}$$

Other uses Brewing water:

yeast washing / dilution - adding water to yeast

Evaporation Rates 4-5 % volume / hr

\* Different Schemes to minimize evaporation losses

## Process Water

- Water used Washing/Sterilizing different components
  - mixing detergents
  - heat exchangers i.e. refrigerators, heating, etc.

## General purpose water

- Drinking, "office use"

## Service water

- Boiler Feed

## Water Chemistry

- Mash pH

Water Hardness - total positively charged (Ca) (Mg) cations

Water Alkalinity - total (HCO<sub>3</sub>) (CO<sub>3</sub>) anions

Bi-carbonate      Carbonate

Ca<sup>2+</sup> Mg<sup>2+</sup> - Lower pH  
HCO<sub>3</sub> CO<sub>3</sub> - Buffer pH

## Salt Forms

<u>Gypsum</u>	- Calcium Sulfate	- CaSO <sub>4</sub> · (2H <sub>2</sub> O)	- Ca = 23% SO <sub>4</sub> = 56%
	Calcium Chloride	- CaCl <sub>2</sub> · (2H <sub>2</sub> O)	- Ca = 27% Cl <sub>2</sub> = 48%
<u>Epsom Salts</u>	- Magnesium Sulfate	- MgSO <sub>4</sub> · (7H <sub>2</sub> O)	- Mg = 10% SO <sub>4</sub> = 39%
<u>Chalk</u>	- Calcium carbonate	- CaCO <sub>3</sub>	- Ca = 40% CO <sub>3</sub> = 60%
<u>Table Salt</u>	- Sodium Chloride	- NaCl	- Na = 40% Cl = 60%

\* H<sub>2</sub>O hydration shell

## Acceptable levels

Cl <sup>-</sup> - 50 - 100 ppm (5g > 11050 = 350 ppm)	- Palate Fullness	Mg <sup>2+</sup> - 0 - 70 ppm - Bitterness
Ca <sup>2+</sup> - 5 - 200 ppm	- Mash Chemistry	
Na <sup>+</sup> - 2 - 100 ppm	- Salty	
SO <sub>4</sub> <sup>-2</sup> - < 500 ppm	- Dry, Sharp	

Ex1 Desire 200 ppm Ca in Water containing 50 ppm  
Volume = 100 Liters

$$\text{Ca Required: } 200 - 50 = 150 \text{ ppm} = \frac{150 \text{ mg}}{\text{liter}} \quad (1 \text{ ppm} = \frac{1 \text{ mg}}{\text{L}})$$

$$\text{Total Ca Required: } \frac{150 \text{ mg}}{\text{L}} \cdot \underline{100 \text{ L}} = 15000 \text{ mg}$$

$$\text{Total Gypsum Required: } \text{CaSO}_4 = 23\% \text{ Ca} \rightarrow \frac{15,000 \text{ mg}}{0.23} = \boxed{65,217 \text{ mg gypsum}}$$

### Residual Alkalinity

Mash Target: 5.2 - 5.8  
pH

- Limits Phenol extraction from Husk and color formation
- Improves protein coagulation
- Improves mash bed filterability

Water hardness - (See previous definitions) - important in mash chemistry  
Water alkalinity - Buffers acidification

### equivalent units

	M.W	Valence	equiv wt	PPM per °dH
Ca	40 g/mol	+2	20	7.14 ←
Mg	24.3	+2	12.2	4.36 ←
CO <sub>3</sub>	60	-2	30	10.7 ←
HCO <sub>3</sub>	61	-1	61	21.8 ←
CaCO <sub>3</sub>	100		50	17.85 ←

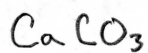
equivalence - common denominator

$$\text{PPM per dH} = \frac{\text{eq. wt}}{2.8}$$

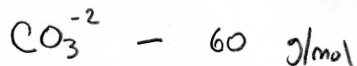
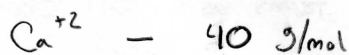
$$1^\circ \text{dH} = \frac{10 \text{ mg}}{\text{L}} \text{ CaO}$$

Example - Calculating equivalent wt

3



1005



$$\text{eq. wt} = \frac{40}{2} + \frac{60}{2} = 50$$

### Water Reports

ex1

	PPM
Calcium	34
Magnesium	4
(CaCO <sub>3</sub> ) Alkalinity	54
(CaCO <sub>3</sub> ) Hardness	102

Calcium and Magnesium contribute to hardness.



$$\frac{34 \text{ PPM Ca}}{20 \text{ eq wt Ca}} = 1.70 \text{ milliequivalents}$$

$$\frac{4 \text{ PPM Mg}}{12.2 \text{ eq wt Mg}} = 0.33 \text{ milliequivalents}$$

\* milliequivalents are the common denominator.

→ Can express in terms of CaCO<sub>3</sub>, Ca, Mg, HCO<sub>3</sub>, etc.

$$1.70 + 0.33 = 2.03 \text{ milliequivalents}$$

\* Expressed as CaCO<sub>3</sub> → 2.03 · 50 (eq wt CaCO<sub>3</sub>) =

$$\boxed{102 \text{ ppm CaCO}_3}$$

\*\*\* This is how 34 ppm Ca and 4 ppm Mg are equal to 102 ppm hardness.

Paul Kolbach →

3.5 equivalents Ca and 7.0 equivalents of set

1 equivalent of  $\text{CaCO}_3$  in terms of pH changes

### Residual Alkalinity

$$\text{RA (mEq)} = \frac{\text{PPM } \text{CaCO}_3}{\text{eq wt } \text{CaCO}_3} - \left[ \frac{\left( \frac{\text{PPM Ca}}{\text{eq wt Ca}} \right)}{3.5} + \frac{\left( \frac{\text{PPM Mg}}{\text{eq wt Mg}} \right)}{7} \right]$$

Convert mEq to PPM  $\text{CaCO}_3$  by multiplying by eq. wt.  $\text{CaCO}_3$  (50).

### Predicting Mash pH

$$\text{Mash pH} = 5.8 + (0.03)(\text{RA})$$



pH of mash is it  
were made with DI water

$$* \text{ RA} = \text{needs to be in terms of } ^\circ\text{dH}$$



Refer to Chart  
from before.

\*  $1^\circ\text{dH}$  causes a pH change of 0.03

### Example

④

If mash is performed with water from previous water report:  
What pH would it have?

Using Residual Alkalinity equation:

$$RA \text{ (mEq)} = \frac{54 \text{ ppm } CaCO_3}{50 \text{ eq wt } CaCO_3} - \left[ \frac{\left( \frac{34 \text{ ppm Ca}}{20 \text{ eq wt Ca}} \right)}{3.5} + \frac{\left( \frac{4 \text{ ppm Mg}}{12.2 \text{ eq wt Mg}} \right)}{7.0} \right]$$

$$RA = 1.08 - (0.486 + 0.047)$$

$$= 0.55 \text{ mEq}$$

$$0.55 \text{ mEq} \cdot 50 \text{ eq wt } CaCO_3 = 27.5 \text{ ppm } CaCO_3$$

Want to convert ppm  $CaCO_3$  to  $^{\circ}dH$ :

$$\text{From } \frac{\text{eq wt } CaCO_3}{2.8} \rightarrow \frac{50}{2.8} = 17.85 \frac{\text{ppm } CaCO_3}{^{\circ}dH}$$

$$\frac{27.5}{17.85} = 1.54 ^{\circ}dH$$

$$pH = 5.8 + (0.03)(1.54)$$

$$\boxed{= 5.846 \rightarrow \text{too high}}$$

\* Would add  $CaCl_2$  or  $CaSO_4$  or  $MgSO_4$  to lower pH

## Manipulating Mash pH with other methods

\* Can add acids → 100% Lactic acid  
37% Hydrochloric  
98% Sulfuric

— 58 grams —	[ to reduce pH by 0.1
— 63 grams —	
— 32 grams —	



Per 100 kg of grain

### using acidulated Malt

Acidulated malt in Distilled Water has pH → 3.5

↳ Maillard Reactions: Acidic melanoidins

<u>Weighted grist %</u>			
	<u>pH</u>	<u>%</u>	
2-Row	5.8	95	= 5.510
Acidulated	3.5	5	= 0.175
			+

5.685 pH

↓

This value would be placed into  
Predicting Mash pH equation if further  
Salt additions are required.